Management and Conservation Article

Preburn Characteristics and Woodpecker Use of Burned Coniferous Forests

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ABSTRACT Large wildfires are common in many western coniferous forests, and these fires can affect woodpecker reproduction and habitat use. Our objectives were to examine nesting densities, reproductive parameters, and species-specific habitat selection of woodpeckers in a recently burned region of the Black Hills in South Dakota, USA, between 2001 and 2004. Postfire nesting densities were greatest in areas dominated by high prefire canopy cover, and reproductive success averaged >70%. For some species of woodpeckers, factors such as diameter at breast height, burn severity, and distance to unburned patches were important for nest-site selection. Our data indicated that nesting densities of many woodpeckers in the Black Hills were lower than what has been recorded elsewhere following recent, large wildfires in ponderosa pine (*Pinus ponderosa*) forests. Management activities that simulate mixed-severity fire effects and retain higher numbers of large snags are likely to benefit cavity nesters in this region. (JOURNAL OF WILDLIFE MANAGEMENT 72(2):422–427; 2008)

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Recently burned forests constitute an important habitat type for cavity-nesting birds such as woodpeckers (e.g., *Picoides* spp. and *Melanerpes* spp.; Kotliar et al. 2002, Saab and Powell 2005). Bark-probing feeders, such as black-backed woodpeckers (*Picoides arcticus*) and hairy woodpeckers (*P. villosus*), are attracted to recently burned areas because of increases in populations of wood-boring beetles (Cerambycidae and Buprestidae; Hutto 1995). Additionally, forest openings created by fire provide more room for foraging maneuvers by aerial flycatchers such as Lewis's woodpeckers (*Melanerpes lewis*) and red-headed woodpeckers (*M. erythrocephalus*; Saab and Dudley 1998, Davis et al. 2000). Lewis's and red-headed woodpeckers may also benefit from an increase in arthropod densities, commonly associated with high postfire vegetation productivity (Hermann et al. 1998, Chen et al. 2006). Snags produced by fire also are important nest and roost sites for a variety of woodpecker species (Saab et al. 2002, Vierling and Lentile 2006).

Fire severity can influence nest-site selection (e.g., Vierling and Lentile 2006), and severity classes typically range from low (surface fire) to moderate (mixed surface fire and torching) to high (stand-replacing fire; Lentile et al. 2005). Smucker et al. (2005) noted that northern flicker (*Colaptes auratus*) and hairy woodpecker densities were high in regions that had experienced high-severity fires as compared to regions where lower-severity fires occurred. Similarly, black-backed woodpeckers have been noted to prefer moderately and severely burned forests over forests that burn under low-severity conditions (Hoyt and Hannon 2002).

In general, fire severity can be influenced by a number of factors, including climate, topography, and prefire forest characteristics (Lentile et al. 2006). However, few studies address relationships between prefire characteristics and burn severity in the context of postfire use by birds (see Saab et al. 2002), and studies addressing these relationships will improve our understanding about how fire affects bird populations (Saab and Powell 2005). Our objectives were to examine the postfire breeding-season dynamics of woodpeckers in a recently burned forest in the context of prefire conditions and postfire effects. Following Saab et al. (2002), we hypothesized that differential woodpecker use of burned habitats would be related to prefire forest conditions and the resulting patterns of severity.

STUDY AREA

The Black Hills was an isolated and forested mountain range rising >1,000 m above the Great Plains of western South Dakota and northeastern Wyoming, USA (Shepperd and Battaglia 2002). The Black Hills was dominated by ponderosa pine (*Pinus ponderosa*), but aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), bur oak (*Quercus macrocarpa*), and white spruce (*Picea glauca*) also occurred (Shinneman and Baker 1997). The historical disturbance regime of ponderosa pine forests in the Black Hills was diverse. Dendrochronologically-based fire studies from the southern Black Hills suggested that low-intensity surface fires burned every 10–30 years, maintaining open, savannah-like forests with large (30–85-cm quadratic mean diam) trees (Brown and Cook 2006). The northern Black Hills was wetter and cooler, and stand-replacing fires occurred approximately every 70 years (Shinneman and Baker 1997). Recent forest landscape structure was influenced by large, stand-replacing crown fires and by small, less severe surface disturbances and, for this reason, contemporary Black Hills fire regimes may be best described as mixed severity (Lentile et al. 2005, Brown and Cook 2006).

In late August and early September 2000, the Jasper Fire burned 33,795 ha, or approximately 7% of the Black Hills National Forest. The Jasper Fire burned under a 10-hour fuel moisture level of 5% and an average wind speed of 31 km (Lentile et al. 2006). The Jasper Fire was located between latitudes 43°41′35″–43°55′48″N, longitudes 103°46′1″–

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104°0′47″W, and elevations approximately 1,500–2,100 m. The Jasper Fire was started by arson in an area that had not burned in the previous century (Shepperd and Battaglia 2002).

METHODS

Nest Searching

We conducted nest searching to document woodpecker nest activity for 4 years beginning the first summer following the fire (2001–2004). Prefire canopy cover has been identified as a potentially good predictor of postfire occupancy by species such as black-backed woodpeckers (Saab et al. 2002). Thus, within the Jasper Fire, we established 6 study sites of 250–400 ha with varying prefire forest canopy cover. Of the study sites, 2 were dominated by high prefire canopy cover (>70%), 2 by medium prefire canopy cover (40–70%), and 2 by low prefire canopy cover (<40%; after Saab et al. 2002). With the exception of one site, none of the sites underwent postfire salvage logging. Salvage logging occurred in 2002 within one high prefire canopy cover site, and the logging activities occurred at the periphery of the study site. We analyzed only data from the unlogged portions of the study area.

We followed nest searching methods described in Dudley and Saab (2003) to find cavities. Within each study site, we established transects every 200 m and searched for nests by walking each transect until we had surveyed the entire unit (Dudley and Saab 2003). We conducted annual surveys from late April through early July and, once we found nests, we waited until they had fledged or failed to record nest tree and microhabitat measurements. Nest searching effort focused on a broad group of woodpeckers in 2001–2003, but we concentrated efforts on black-backed and Lewis's woodpeckers in 2004 due to the importance of these species as fire-sensitive species and to a concurrent decrease in personnel.

Reproductive Success

Once we located nest cavities, we visited them every 3–4 days and observed adult behaviors to determine approximate stage of the nest cycle. In 2001, we determined nest activity based on observations of parental activity. From 2002 to 2004, we monitored nests using a telescoping camera and used those data to determine the daily survival rates and nest success (no. of nests successful in fledging ≥1 young) using the Mayfield method (Mayfield 1975). Because of small sample sizes for some species, we calculated reproductive success only for species with ≥17 nests.

Nest-Site Selection

We recorded cavity and microhabitat characteristics for nest sites and random sites following the Breeding Biology Research and Monitoring Database protocol (Martin et al. 1997). For each nest tree, we recorded tree and cavity height, cavity age (i.e., whether the cavity was newly excavated), snag species, decay class, and diameter at breast height. In addition to nest tree characteristics, we recorded a variety of other micro-site characteristics such as cover type (i.e., aspen or pine), shrub density, and snag density. Within 5 m of the nest tree or random tree, we recorded the number of shrub stems in 3 categories (dbh): <2.5 cm, 2.5–5.0 cm, and 5–8 cm. We determined snag density by counting all snags ≥8 cm diameter at breast height within 11.3 m (0.04 ha) from the nest or random tree. We repeated these habitat measurements at random sites centered upon a random tree. We selected random trees by using a random number generator to determine coordinates for random sites, and we paired random sites by cover type and prefire canopy cover type with nest sites that occurred within the same study sites.

Pre- and Postfire Forest Characterization

We obtained prefire stand condition and structural information from the Black Hills National Forest Resource Information System (RIS) database (Lentile et al. 2006). We gathered topographical information including elevation, slope, and aspect from the 30-m-resolution digital elevation model (DEM) for the Black Hills. We combined RIS and DEM layers with the postfire severity layer to produce a Geographic Information System (GIS) layer (ArcView GIS) containing topographical, prefire structural, and burn-severity attributes. Prefire characteristics of the Jasper Fire and postfire effects in this forested landscape have been reported elsewhere (Lentile et al. 2006).

Statistical Analyses

We modeled species-specific woodpecker habitat selection using logistic regression, and we used Akaike's Information Criterion (AIC; Burnham and Anderson 2002) to determine the best model among an a priori set of a fully parameterized model and all of its reduced forms. The global model included nest-tree diameter at breast height (cm), snag density (no. of snags ≥8 cm dbh within 0.04 ha), the percentage of area burned under low severity within 1 km of the nest or random tree, and the minimum distance (m) to unburned edge. Diameter at breast height and snag density have been noted to be important nest-site components for woodpeckers, and distance to unburned edge has been noted to be important because of potential predator recolonization into a burned patch (Saab and Vierling 2001, Hoyt and Hannon 2002, Vierling and Lentile 2006).

Landscapes that burned under low severity had low tree mortality (<1%), predominantly green tree canopies (<25% canopy scorch), and >70% vegetative or needle cover on the ground (Lentile 2004, Lentile et al. 2005). Landscapes that burned under moderate severity had approximately 23% tree mortality, >25% canopy scorch, and 30–70% vegetative or needle cover on the ground (Lentile 2004, Lentile et al. 2005). High-severity sites were characterized by complete tree mortality (>100% blackened canopies) and <30% ground cover (Lentile 2004, Lentile et al. 2005). We determined the percentage of low-, moderate-, and high-severity fire within a 1-km radius around each nest site or random site. We used a 1-km buffer to examine fire-severity effects on woodpeckers because it has been used in other studies and is thought to encompass home ranges of the species in our study region (e.g., Vierling and Lentile 2006). We used the Spatial Analyst extension in ArcView GIS to calculate minimum distances from each nest site or random site to unburned patches.

Table 1. Average density of nests/100 ha (± SE) of woodpeckers nesting in the Jasper Fire in the Black Hills, South Dakota, USA. Due to unequal nest searching efforts among years, estimates for black-backed woodpeckers and Lewis's woodpeckers include 2001–2004; all other woodpeckers include data from 2001 to 2003.

Species	High prefire canopy cover ($n = 2$)	Moderate prefire canopy cover ($n = 2$)	Low prefire canopy cover ($n = 2$)	Overall density
Black-backed woodpecker				
No. of nests	11	8	1	20
Mean density	0.28	0.31	0.03	0.24
SE	0.08	0.08	0.02	0.05
Hairy woodpecker				
No. of nests	40	14	9	63
Mean density	1.7	0.68	0.45	0.95
SE	0.18	0.05	0.05	0.01
Lewis's woodpecker				
No. of nests	0	2	4	6
Mean density	0	0.08	0.14	0.07
SE	0	0.07	0.07	0.02
Northern flicker				
No. of nests	27	6	8	41
Mean density	0.98	0.31	0.27	0.52
SE	0.12	0.02	0.06	0.05
Red-headed woodpecker				
No. of nests	8	3	6	17
Mean density	0.46	0.16	0.14	0.25
SE	0.04	0.04	0.03	0.04
Red-naped sapsucker				
No. of nests	1	0	0	1
Mean density	0.05	0	0	0.03
SE	0.08	0	0	0.06
Downy woodpecker				
No. of nests	2	0	0	2
Mean density	0.09	0	0	0.02
SE	0.11	0	0	0.02
All woodpeckers				
No. of nests	89	33	28	150
Mean density	3.67	0.099	1.56	2.08
SE	0.22	0.09	0.08	0.13

We evaluated a global model using the Hosmer–Lemeshow goodness-of-fit test for each species to ensure that the model adequately fit the data (Hosmer and Lemeshow 2000; $P > 0.61$ for hairy woodpeckers, $P > 0.78$ for northern flickers). In addition to a global model, we considered 12 candidate models based on ecologically plausible relationships for each bird species for which we had found ≥30 nests. These models consisted of all possible combinations of the covariates. Because of small sample sizes, we used AIC corrected for small sample size (AIC_c; Burnham and Anderson 2002) and calculated the difference between the model with the lowest AIC_c score and the remaining models.

We included woodpecker species with sample sizes <6 in the total for all woodpeckers; species with low sample sizes included Lewis's woodpeckers, red-naped sapsuckers (*Sphyrapicus nuchalis*), and downy woodpeckers (*Picoides pubescens*). We did not perform statistical tests to examine differences in nest densities due to small sample sizes between treatments. We performed statistical tests in SAS 9.01 (SAS Institute, Cary, NC).

RESULTS

Nest Density

We found 150 active woodpecker nests during the 4 breeding seasons after the fire, representing 7 different species. Hairy woodpeckers ($n = 63$) and northern flickers ($n = 41$) were the most common breeding woodpeckers. Other breeding woodpeckers included red-headed woodpeckers ($n = 17$), Lewis's woodpeckers ($n = 6$), black-backed woodpeckers ($n = 20$), downy woodpeckers ($n = 2$), and red-naped sapsuckers ($n = 1$).

Woodpecker nest densities within high prefire canopy cover sites were at least twice as high as densities in either moderate or low prefire canopy cover sites (Table 1). We found no black-backed woodpecker nests in 2001, although a small number of adults were noted to forage in the area. Nest densities of all woodpeckers were low in 2001 ($n = 6$), increased in 2002 ($n = 75$), and decreased in 2003 ($n = 57$) and 2004 ($n = 11$).

Reproductive Success

Overall nest success was high (>70%), with 3 out of the 4 species experiencing the highest reproductive success in areas that were dominated by high severity or moderate severity (Table 2). Nest success was high in 2002 (78%; $n = 73$ nests) and decreased in subsequent years from 73% in 2003 ($n = 57$ nests) to 67% in 2004 ($n = 9$ nests). Predation was the major cause of nest failure and increased between 2002 and 2004; 27% of nest failures were due to depredation in 2002 (4 of 15

Table 2. Reproductive variables of woodpeckers between 2002 and 2004 in the Jasper Fire in the Black Hills, South Dakota, USA, in nests located within burned patches of high, moderate, or low severity. We present daily survival rates (± SE) for survival rates across years. The percent reproductive success represents the number of nests successful in fledging ≥1 young.

Species	High severity	Moderate severity	Low severity
Black-backed woodpecker			
No. of nests monitored	10	6	5
Daily survival rate	0.995	0.982	0.986
SE	0.005	0.12	0.014
% reproductive success	80.0	50.0	60.0
Hairy woodpecker			
No. of nests monitored	24	14	18
Daily survival rate	0.994	0.992	1.00
SE	0.003	0.005	0.0
% reproductive success	79.1	71.4	100.0
Northern flicker			
No. of nests monitored	6	11	12
Daily survival rate	1.00	0.994	0.984
SE	0.0	0.006	0.015
% reproductive success	100.0	72.7	50.0
Red-headed woodpecker			
No. of nests monitored	7	4	6
Daily survival rate	0.986	0.992	0.968
SE	0.008	0.007	0.014
% reproductive success	57.1	75.0	16.7

failures), 61% in 2003 (8 of 13), and 67% in 2004 (2 of 3). Only one nest failed due to breakage of the nest tree.

Nest-Site Selection

We analyzed vegetation data on 149 nest and 151 random sites. The number of plots used for vegetation analyses is slightly less than the number of nests monitored because one nest tree was used multiple times and was only included once in the analysis. We collected multiple habitat measures for all species, but present data only for woodpeckers with ≥17 nests (Table 3). We only conducted logistic regression analysis at the species level for hairy woodpeckers and northern flickers, for which we had sufficient sample sizes. The percent low-severity fire within a 1-km buffer, the distance to an unburned patch, and diameter at breast height were included in the top models for both of these species (Table 4). These models indicated a positive relationship with diameter at breast height and distance to an unburned patch and a negative relationship with the percent low-severity fire for both species (Table 5).

DISCUSSION

Areas with high prefire canopy cover were more likely to burn severely, but factors such as tree size, tree density, and slope were also influential in determining fire severity in the Jasper Fire (Lentile et al. 2006). Woodpecker density has been associated with the availability, density, and distribution of suitable snags in the landscape (Mannon and Meslow 1984, Raphael and White 1984, Dixon and Saab 2000), and areas of high severity generated a high number of snags compared to the areas that burned under low and moderate severity. Nesting densities of breeding woodpeckers were generally 2–3 times higher in burned pine forest in Idaho, USA, as compared to our burned site in the Black Hills (Saab et al. 2007). Notably, both burn specialist woodpeckers (black-backed and Lewis's woodpeckers) occurred in low densities in the Black Hills as compared to burned forests in Idaho. The Black Hills is an isolated forested island amidst the Great Plains, and its isolation from the rest of the species' range may be partially responsible for low densities we found. Additionally, low density of Lewis's woodpeckers relative to burned pine forest in Idaho (0.21 nests/100 ha in ID vs. 0.07 nests/100 ha in the Black Hills) may be because Lewis's woodpeckers require larger snags in which to nest ($\bar{x} = 39$ cm dbh) compared to those that are randomly available in the landscape. Spiering and Knight (2005) recorded low hairy woodpecker densities (0.08 birds/ha; CV = 19.3%) in unburned Black Hills forests and attributed low densities of woodpeckers to the patchy distribution and infrequent occurrence of large snags.

Daily survival rates of species were high following the Jasper Fire and were comparable to those recorded in other studies (Saab and Dudley 1998, Saab and Vierling 2001). Predation increased in the years following the Jasper Fire. Saab and Vierling (2001) attributed a similar pattern observed in burned pine and cottonwood forests to postfire predator recolonization of sciurid predators. Sciurids were not common in our study sites in the initial years following the fire (K. Vierling, University of Idaho, personal observation), but these predators have been noted to increase over time as vegetation recovery occurs following fire (Fisher and Wilkinson 2005).

Although sample sizes of only 2 woodpeckers allowed us to analyze habitat selection at the species level, the best model for both species included a positive relationship with distance to unburned forest edge and diameter at breast height and a negative relationship with percent low-severity burns within

Table 3. Average measurements (± SE) of woodpecker nest sites and random sites in the Black Hills National Forest, South Dakota, USA, between 2001 and 2004. Only species with ≥17 nests are included below.

Species	*n*	Mean dbh (cm) of focal tree	SE	Mean distance (m) to unburned edge from focal tree	SE	Mean % low-severity fire within 1 km of focal tree	SE	Mean snag density within 11.3 m of focal tree	SE
Black-backed woodpecker	20	25.7	1.09	605.95	61.0	20.8	1.90	26.8	4.17
Hairy woodpecker	63	26.1	0.92	669.3	48.3	23.6	1.04	16.0	1.18
Northern flicker	41	29.4	1.40	565.9	68.0	23.1	1.59	11.1	1.31
Red-headed woodpecker	17	27.4	1.30	219.4	34.8	24.9	1.80	2.9	0.47
Random sites	151	19.8	0.73	168.7	10.8	24.9	0.54	13.3	0.94

Table 4. Model selection based on logistic regression to predict woodpecker nest site selection in burned coniferous forest in the Black Hills, South Dakota, USA, 2001–2004. We present models (K = no. of parameters) with differences in Akaike's Information Criterion adjusted for small sample size (ΔAIC_c) <2.0 below for hairy woodpeckers and northern flickers.

Species	Candidate model	Log likelihood	K	ΔAIC_c	Akaike wt
Hairy woodpecker	Model 1: distance to unburned, % low-severity fire, dbh	−55.08	4	0	0.48
	Model 2: distance to unburned, % low-severity fire	−56.68	3	1.31	0.25
Northern flicker	Model 1: distance to unburned, % low-severity fire, dbh	−44.86	4	0	0.59
	Global model: distance to unburned, % low-severity, dbh, snag density	−44.85	5	1.75	0.25

a 1-km radius of the nest tree. The nest-site selection analyses for northern flickers and hairy woodpeckers indicated a positive relationship with diameter at breast height. Woodpeckers in the Jasper Fire generally nested in larger-diameter snags than were available in the landscape, but a range of sizes was used by the various species. Consistent with our findings, several authors have found that black-backed woodpeckers and hairy woodpeckers use smaller snags for nesting, whereas Lewis's woodpeckers and northern flickers use larger snags than do other woodpeckers (Raphael and White 1984, Saab and Dudley 1998).

Nests were generally a greater distance from unburned edges than were random sites, which may be related to mammalian predator pressures. Avian nest predators such as the common raven (*Corvus corax*) and Steller's jay (*Cyanocitta stelleri*) were not present in the Black Hills. Likely potential mammalian nest predator species noted in the area included raccoon (*Procyon lotor*), least chipmunk (*Tamias minimus*), and red squirrel (*Tamiasciurus hudsonicus*). Saab and Vierling (2001) concluded that unburned habitats may serve as source habitats for nest predators, and Fisher and Wilkinson (2005) note that higher densities of sciurids are found in unburned habitat compared to burned patches due to the availability of forage and cover.

Woodpeckers in the Black Hills preferred nesting in areas burned by moderate- and high-severity fires. Smucker et al. (2005) also noted the relationship between burn severity and woodpeckers, which may be related to lower predator pressure, the creation of high numbers of snags, or the creation of an abundant prey base of some woodpecker species (Saab and Vierling 2001, Hoyt and Hannon 2002, Lentile et al. 2005). The association with high severity occurs across species with different foraging behaviors and has been noted to be important for aerial flycatching red-headed woodpeckers (Vierling and Lentile 2006), bark probers such as hairy woodpeckers, and ground foragers such as northern flickers. Although the mechanisms driving habitat selection may differ between species (i.e., fires creating additional foraging opportunities or creation of nesting habitat), high-severity effects appear to be important for multiple woodpecker species as long as greater numbers of larger snags are retained throughout the landscape.

Burn severity is influenced by a variety of factors relating to weather, vegetation, and topography (Baker and Ehle 2001). The Jasper Fire was a mixed-severity fire, creating a mosaic of fire effects, with some surviving vegetation, some patches of dead trees, and some forest openings. Unlike other large western wildfires, patches of high severity were relatively small in the Jasper Fire (approx. 8 ha on average, compared to 100–1,000 ha observed in other fires in ponderosa pine forests; Lentile et al. 2006), and these components provided important habitat attributes for nesting woodpecker species.

MANAGEMENT IMPLICATIONS

The factors that influenced woodpecker nest-site selection in a recently burned forest included greater distances to unburned patches, a higher proportion of moderate- to high-severity effects in the landscape, and larger snags. Although fire planning that encourages low-severity fires is important, we recommend that fire planning provide for opportunities where mixed-severity fires can occur (i.e., encourage a mosaic of fire effects including patches of dead trees, as well as live trees and forest openings). Large snags and trees (that will eventually become snags) are found at low densities in the Black Hills (Spiering and Knight 2005). We recommend that snags $\geq$26 cm diameter at breast height be retained because this represents the smallest

Table 5. Predictor variables, parameter estimates (β), standard errors, odds ratios, and 95% confidence intervals for the best model explaining hairy woodpecker nest-site selection and northern flicker nest-site selection in the Black Hills, South Dakota, USA, 2001–2004. We considered confidence intervals that do not contain 1 statistically significant.

Species and effect	β	SE	Odds ratio	Odds ratio CI
Hairy woodpecker				
Dbh	0.0511	0.0290	1.052	0.994–1.114
% low severity	−0.1069	0.0349	0.899	0.839–0.962
Distance to unburned edge	0.00992	0.0017	1.010	1.007–1.019
Northern flicker				
Dbh	0.1205	0.0319	1.128	1.060–1.201
% low severity	−0.0825	0.0373	0.921	0.856–0.991
Distance to unburned edge	0.0071	0.00154	1.007	1.004–1.010

snag size used by commonly nesting woodpecker species in our study (i.e., hairy woodpeckers), and a range of snag sizes larger than this would encompass the majority of nesting woodpecker species in this region (Saab et al. 2002).

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